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Firm or Individual name	David A. Dagg, Reg. No. 37,809 Steubing McGuinness & Manaras LLP
Signature	David A. Dagg
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Specification and drawings, as originally filed, with Application for Patent Serial No: **2,299,038**, on February 21, 2000, by **NORTEL NETWORKS CORPORATION,** assignee of Peter J. Ashwood-Smith, for "MPLS Application to Optical Cross Connect Using Wavelength as a Label".

CERTIFIED COPY OF PRIORITY DOCUMENT

L. Lachance

Agent certificateur/Certifying Officer

September 28, 2005

Date

Canada

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ABSTRACT

A label switching routing protocol for establishing a datapath as a sequence of locally unique labels in an optical communications network, is provided. A wavelength on an optical cross-connect is considered as a label or one portion of a label. Timeslots may be assigned to designated wavelengths so as to form the second portion of the label. An optical time cross-connect (OTXC) capable of wavelength conversion from an input to an output interface creates the datapath based on wavelength to wavelength substitution, under the control of a multi-protocol label switching (MPLS) protocol.

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MPLS APPLICATION TO OPTICAL CROSS-CONNECT USING WAVELENGTH AS A LABEL

BACKGROUND OF THE INVENTION

Field of Invention

The present invention relates generally to optical communications systems and particularly to label distribution protocols in an optical transmission system using wavelength division multiplexing (WDM).

Related art

Optical networks include a plurality of optical transmission lines and allow high bandwidth data communications. High speed data can be modulated on light waves and transmitted through the optical network. Wavelength division multiplexing (WDM) is a technique for modulating different electrical data signals on distinct light wave carriers having different frequencies.

A wavelength is an end-to-end optical channel, or path of the same frequency from source to destination across the optical network. However, in practice, to achieve long reach and to avoid wavelength blocking, a wavelength may change frequency through regeneration or wavelength translation. The term "path" is understood to mean a set of links directly connecting the port of one node to the port of another node. "End-to-end" means from an end-router to another end-router.

The transport capacity required to accommodate the growth of communications traffic is provided by optical links using dense wavelength division multiplexing (DWDM) having increased capacity and longer reach. In addition, optical cross-connect (OXC) switches are used in DWDM networks as a platform for functional integration and network management.

In DWDM networks the main resource is the wavelength. For rapidly setting up end-to-end connections signaling and routing protocols are used. OXCs using wavelength routing and signaling protocols are considered fast wavelength switches having more stringent speed, timing and control

requirements compared to conventional OXCs, allowing fast end-to-end connectivity.

Another requirement for DWDM networks is the ability to respond quickly to unpredictable traffic intensities and patterns. The Optical Internet is developing towards the optical layer eventually being directly responsive to the IP service layer according to changing traffic situations. To achieve a unified packet and optical switched network architecture, standard routing and signaling protocols may be adapted to the specific requirements of the wavelength routed networks. Known standard signaling and routing protocols are OSPF (open shortest path first), IS-IS (intermediate system - intermediate system), PNNI (private network - network interface), and MPLS/LDP (multi-protocol label switching / label distribution protocol). The signaling system seven (SS7) used in voice networks may also be considered.

There is a need for an optical label switching (OLS) to provide a unified routing protocol to control layer 1 and layer 2 hardware in an MPLS-enabled IP network.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a new routing protocol which alleviates totally or in part the drawbacks of the prior art.

It is another object of the present invention to broaden the MPLS lambda (λ) switching optical scope to additionally address the SONET hierarchy by making the constrained routing LDP (CR-LDP) a common connection oriented signaling protocol for time, frequency, and statistically multiplexed paths.

Still, another object of the present invention is to apply an MPLS-like approach to the optical switch to create an optical label switch where λ represents the label , or a portion of the label to be distributed.

According to one aspect of the invention, a label substitution routing protocol for establishing a datapath as a sequence of locally unique labels in

an optical communications network, wherein each label is a wavelength frequency, is provided. The wavelength may constitute a label, or one portion of a label, while the second portion is formed by assigned timeslots.

According to another aspect of the invention, an optical cross-connect (OXC) for creating a datapath in an optical communications network, is provided. The OXC is capable of wavelength conversion from an input to an output interface so as to provide wavelength to wavelength substitution along the datapath, under the control of a MPLS protocol.

Advantageously, the invention allows one routing protocol to control layer 1 and layer 2 hardware, and this greatly simplifies the network. It brings constrained based routing to the optical and time domains (where it previously existed in the statistical domain), while performing routing at light speed.

The "Summary of the Invention" does not necessarily disclose all the essential features for defining the invention which may reside in sub-combinations of the disclosed features.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be now explained by way of example only and with reference to the following drawings.

Figure 1illustrates the principle of frequency to frequency routing according to the invention;

Figure 2 illustrates λ and time (τ) labels independently managed by the CR-LDP protocol;

Figures 3a and 3b illustrate the problem associated with cross-connecting two optical paths having different transmission speeds;

Figure 4 illustrates wavelength mapping of a message carrying a composite label;

Figure 5 illustrates the functions of an optical time cross-connect (OTXC) according to the invention;

Figure 6 illustrates wavelength mapping of a message in a optical switch where the output and input speeds and framing are the same;

Figure 7 illustrates wavelength mapping in an optical switch where the output speed is greater than the input speed, assuming SONET framing;

Figure 8 illustrates wavelength mapping in an optical switch similar to the mapping of Figure 7 but for lower output and input speeds; and

Figure 9 illustrates wavelength mapping in an optical switch where the output speed is smaller than the input speed.

Similar references are used throughout the description to denote similar parts.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

One of the many ways for routing an end-to-end routing in a communications network is broadcasting. Broadcasting implies sending a message from a source node to a destination node by sending the message to all nodes in the network, without providing directions, and finally stopping when reaching the destination.

The routing of a message in a communications network can be performed by the source node, or on a hop by hop basis. The source routing provides a list of places where the packet should go which leads to the destination. In a hop by hop routing, the packets are continuously asking for directions at each node until reaching the destination.

Using the above techniques, one can imagine sending a messenger ahead of the message to reserve capacity for the transmitted data, and for distributing signs at each node indicating where the packet has to go. This is a signaling protocol called the label substitution protocol (LSP) used with the asynchronous transmission mode (ATM). Examples of labels used with various protocols are "DLCI" label that travels with the frame relay protocol, "timeslot" for the time division multiplexing (TDM) protocol, or "LCN" for X25 protocol.

The multi-protocol label switching (MPLS) is a signaling protocol defined to setup, maintain, and release wavelength paths in an optical network. Similar to the label distribution protocol (LDP), the MPLS treats wavelengths as labels. The main function of the MPLS protocol is connection management by wavelength grouping and mapping, or label banding, according to combinations of: destination addresses, and type of service (ToS) information. The ToS information may be provided according to optical equivalence classes (FECs) and distributed with the label banding. The MPLS protocol can also create various types of connections, one being the explicit routed (ER) path as defined in the Constraint Routed LDP (CR-LDP). The CR-LDP protocol is an efficient solution for core network traffic engineering as regarding the quality of service (QoS) guarantees, path optimization, and flexibility.

Figure 1illustrates the principle of frequency to frequency routing according to the invention. An optical label switch **10** comprises a λ routing control entity **12** and the photonic fabric **14** for connecting the ends of two or more cables ending with connectors **16** - **19**. Suppose that λ_1 arriving on line **15** is to be frequency switched to line **13**. The frequency to frequency switching is mainly due to the fact that the input and output speeds of switch **10** are different, as it will be discussed later in connection with Figures 2a and 2b. For routing purposes, λ_1 is switched to λ_2 using the frequency, or λ, as a label for the MPLS protocol to distribute across the network. It is to be noted that λ may constitute the entire label or just a portion of the label. No new protocols are needed for further routing as the LDP protocol is used to setup OSPF routes, and the CR-LDP protocol can engineer the traffic

Figures 2a and 2b illustrate the problem for cross-connecting two optical paths having different transmission speeds as mentioned before. In Figure 2a the problem for cross-connecting two optical paths having different transmission speeds is illustrated. The optical cross-connect (OXC) **20** is a slow provisioned wavelength switch with optical interfaces at typically SONET

OC-48 or OC0192 rates with an electrical or optical core. The conventional OXC **20** can not cross-connect line **22** which is an OC-48 to line **24** which is an OC-192 unless the connection is performed at the lowest supported rate. It is to be noted that having all optical paths running at the same speed is not possible as physical media differences may dictate lower speeds on certain links. As shown, in Figure 2b, optical cross-connect (OXC) **20** can connect, two transmission lines having same transmission speed like for example optical carriers (OC-48) **22**. This wastes 3xOC-48 or 7.5Gig for the example of Figure 2b, which is an enormous amount of bandwidth

Figure 3 illustrates λ and time (τ) labels independently managed by the CR-LDP protocol. The labels are considered in a hierarchy with the lambda (λ) labels on top of the timeslot (τ) labels, which in turn are hierarchically above the statistically multiplexed (SHIM) labels. The CR-LDP protocol sessions will manage each level of the hierarchy independently.

Figure 4 illustrates wavelength mapping of a message carrying wavelength and time as a single composite label (λ_n; $\tau_{k\text{-}p}$). The CR-LDP protocol is mapping the messages flowing from west to est on link **40** to carry a label that consists of a wavelength (λ_n) and optionally a set of timeslots ($\tau_{k\text{-}p}$) finally forming a single composite label label (λ_n; $\tau_{k\text{-}p}$). However, it is possible to have a label that arrives on one link to be logically split into two labels as it flows back toward the source.

Arrow **41** represents a single mapping message in all examples. It is also assumed that an Internet protocol (IP) like point to point protocol (PPP) or transport communications protocol (TCP)channel is available for CR-LDP/TCP/IP.

The MPLS protocol establishes a sequence of locally unique labels and programms generic hardware such that the label on an input interface is switched to another label on an outgoing interface. This is the pure label switching. As discussed before, a wavelength on optical cross-connect can be considered a label and therefore, any optical cross-connect capable of

wavelength conversion from an input to an output interface can be controlled by MPLS. Thus, according to the invention, an MPLS datapath being wavelength to wavelength substitution is created. The optical cross-connect also includes time division multiplexing equipment for providing statistically multiplexed, frequency division multiplexed, and time division multiplexed paths, under the control of said MPLS protocol.

Figure 5 illustrates the functions of an optical time cross-connect (OTXC) according to the invention. Optical time cross-connect **50** receives four wavelengths ($\lambda_1 ... \lambda_4$) as input on OC-48 carriers. The optical switch **50** performs pure optical cross-connect by mapping λ_1 on link **42** to λ_2 on link **44** as the two links have same transmission speed. Where the speeds do not match, the CR-LDP protocol performs electrical/time sub wavelength switching as for example the two wavelength with composite labels (λ_2; $\tau_{48\text{-}95}$), and (λ_3; $\tau_{0\text{-}23}$) from input links **44** and **45** to output link **46**. The label of the wavelength on link **46** include λ_3 and variable size timeslots ($\tau_{0\text{-}47}$) and ($\tau_{48\text{-}72}$) are assigned forming a second portion of the label in this case. If the wavelength has already a timeslot attached, as for example composite label (λ_4; τ_0) shown on line **47**, the connection is performed by maintaining same wavelength and assigning timeslots (τ_0 and τ_{190}).

Figure 6 illustrates wavelength mapping of a message in a optical switch **20** where the output **24b** and input **24a** speeds and framing are the same. In this case, the switch is pure optical, performing frequency to frequency switching.

Figure 7 illustrates wavelength mapping in an optical switch where the output speed OC-192, link **24**, is greater than the input speed OC-48, link **22**, assuming SONET framing. A subset of timeslots are assigned for λ_1 on output **52** to all timeslots on input **54**. Input **54** includes in this example four OC-48, links **22a**, **22b**, **22c**, **22d**, propagating four mappings having four wavelength $\lambda_1 ... \lambda_4$, and same assigned timeslots $\tau_{0\text{-}47}$. The example of Figure 7 may represent four requests for OC-48 as the mappings flow back from link

24 to links **22a** to **22d**.

Figure 8 illustrates a three label request, two for OC-12 and one for OC-24, as the mappings flow back from OC-48, link **22**. This case is similar to the example of Figure 7 and also shows the timeslots allocation for link **58** (λ_3; τ_{0-23}) which is an OC-24 compared to links **56a** ($\lambda 1$;τ_{0-11}) or **56b** (λ_2; τ_{0-11}) which have OC-12 rates.

Figure 9 illustrates wavelength mapping in an optical switch where the output speed OC-24, links **58a** and **58b**, is smaller than the input speed OC-48, link **22**. In such a situation, multiple wavelengths/ timeslots must be allocated. Suppose two composite labels (λ_1, λ_2; τ_{0-23}) arrive on links **58a** and **58b**. This could represent for example a label request for OC-48 as the mapping flows back through a DWDM of OC-24, links **58**. Two OC-24 links, or one OC-48 is required at the input side. The two wavelength labels (λ_1, λ_2; τ_{0-23}) are mapped into one composite label (λ_1; τ_{0-47}) on link **22**.

A routing protocol for establishing a datapath as a sequence of locally unique labels in an optical communications network, was described. The wavelength on an optical cross-connect is considered as a label or one portion of a label. Timeslots may be assigned to designated wavelengths so as to form the second portion of the label. An optical time cross-connect (OTXC) capable of wavelength conversion from an input to an output interface creates the datapath based on wavelength to wavelength substitution, under the control of a multi-protocol substitution label (MPLS) protocol. The time division multiplexing equipment providing statistical multiplexing, or time division multiplexing, or frequency division multiplexing, can also be programmed and controlled by the MPLS protocol. This greatly simplifies the network by bringing constrained based routing to the optical and the time domain, thus making one protocol available for many layers of the network.

Numerous modifications, variations, and adaptations may be made to the particular examples of the invention without departing from the scope of

the intention which is defined in the claims.

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Claims:

1. A label switching routing protocol for establishing a datapath as a sequence of locally unique labels in an optical communications network, wherein said label is a wavelength frequency.

2. A label switching routing protocol for establishing a communication path as a sequence of locally unique labels in an optical communications network, wherein a first portion of each of said labels is a wavelength frequency.

3. The routing protocol as in claim 2, wherein a second portion of each of said labels is a timeslot.

4. The routing protocol as in claim 1 or claim 2, wherein said protocol is a multi-protocol label switching (MPLS).

5. The routing protocol of claim 4, further including a constrained routing label distribution protocol (CR-LDP) for controlling time, frequency, and statistically multiplexed paths.

6. An optical cross-connect (OXC) for creating a datapath in an optical communications network, said OXC for wavelength conversion from an input to an output interface so as to provide wavelength to wavelength substitution along said datapath.

7. The optical cross-connect of claim 5, wherein said wavelength to wavelength substitution is performed under the supervision of a multi-protocol label switching (MPLS).

8. The optical cross-connect of claim 6, further including time division multiplexing equipment for providing statistically multiplexed, frequency division multiplexed, and time division multiplexed paths under the control of said MPLS protocol.

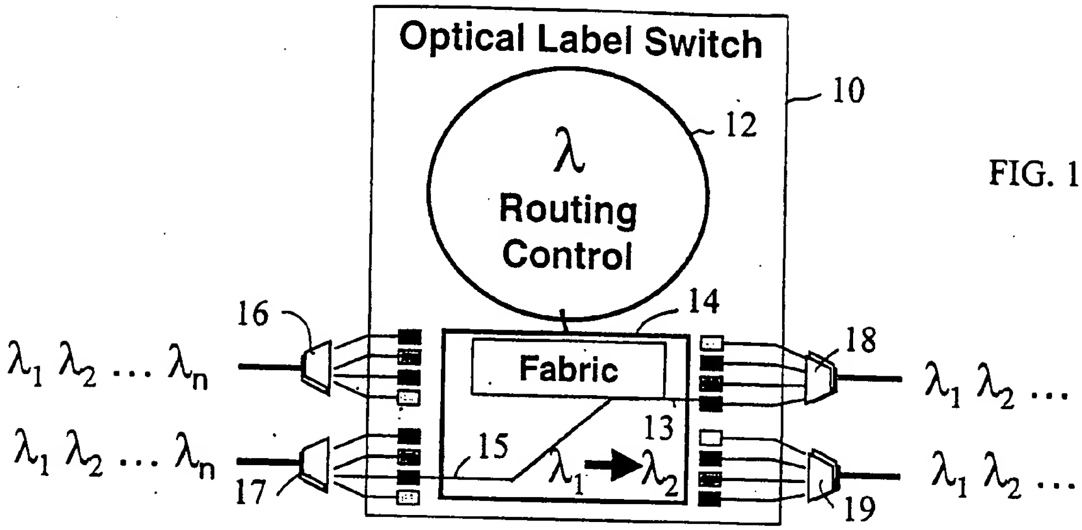

FIG. 1

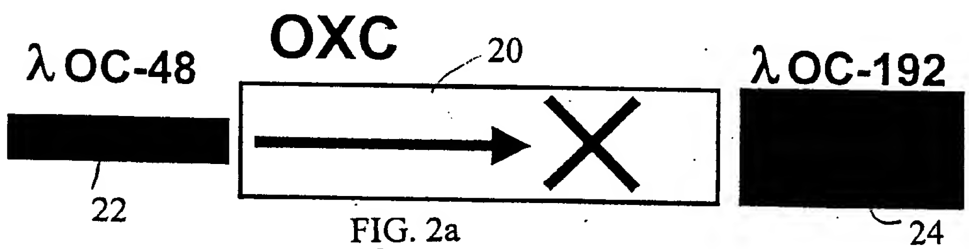

FIG. 2a

FIG. 2

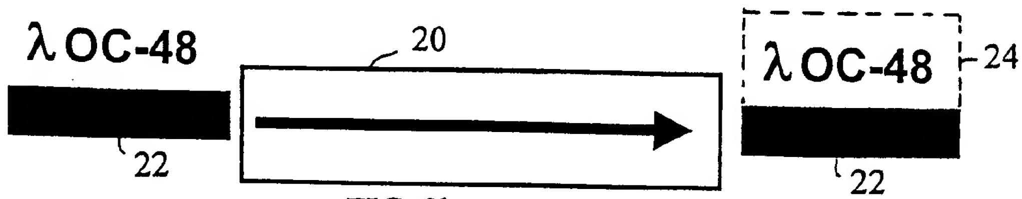

FIG. 2b

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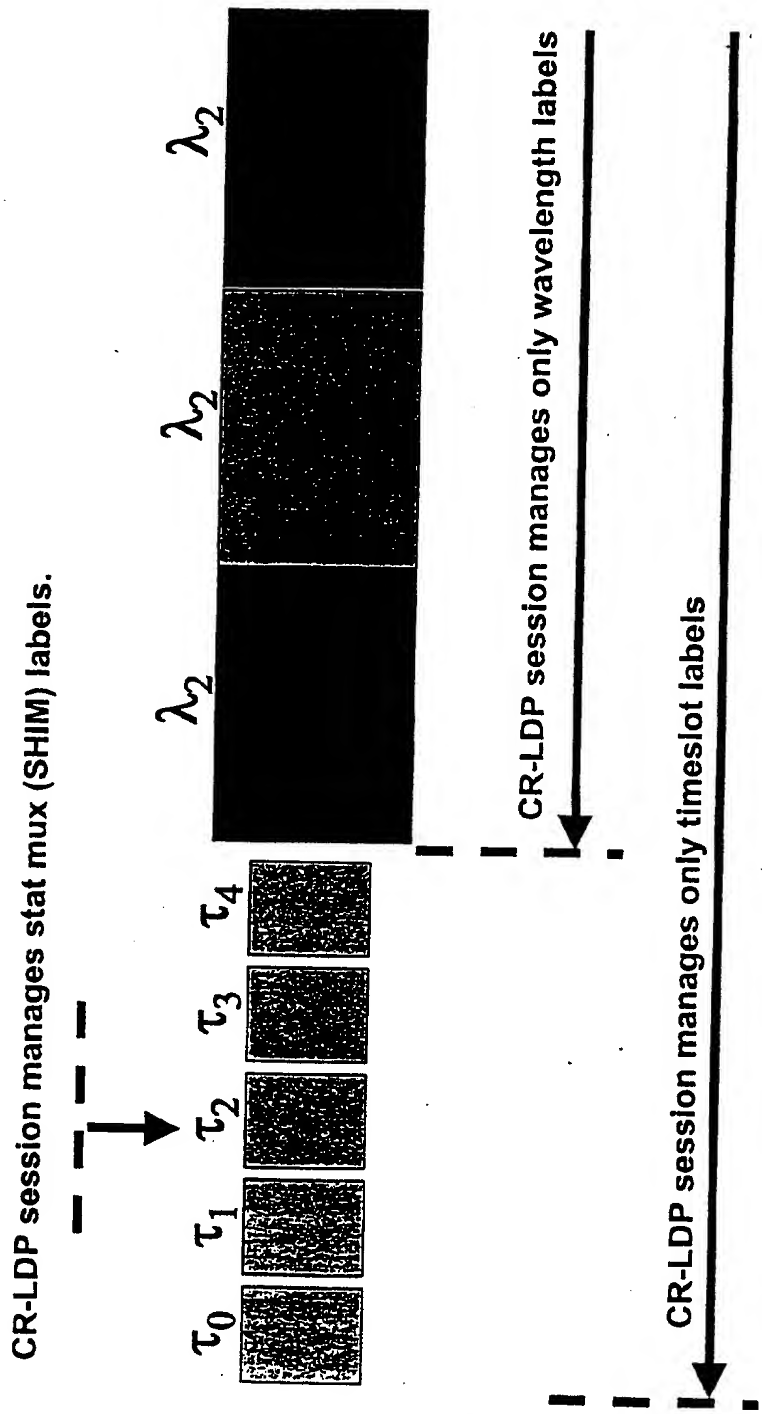

FIG. 3

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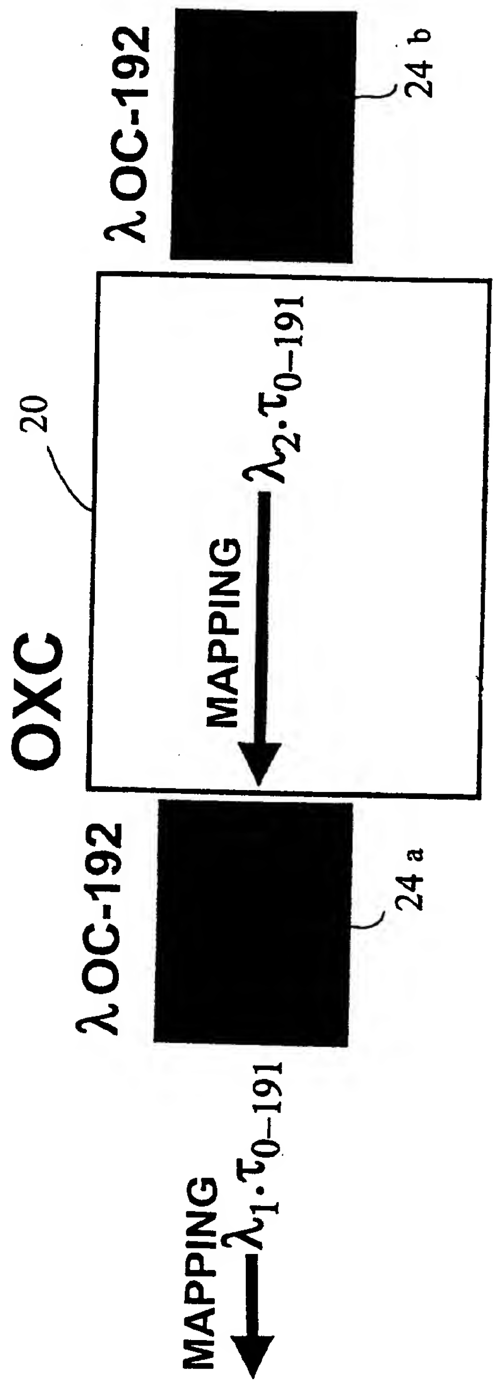

FIG. 6

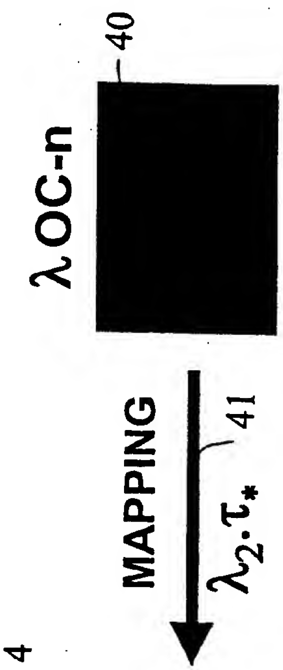

FIG. 4

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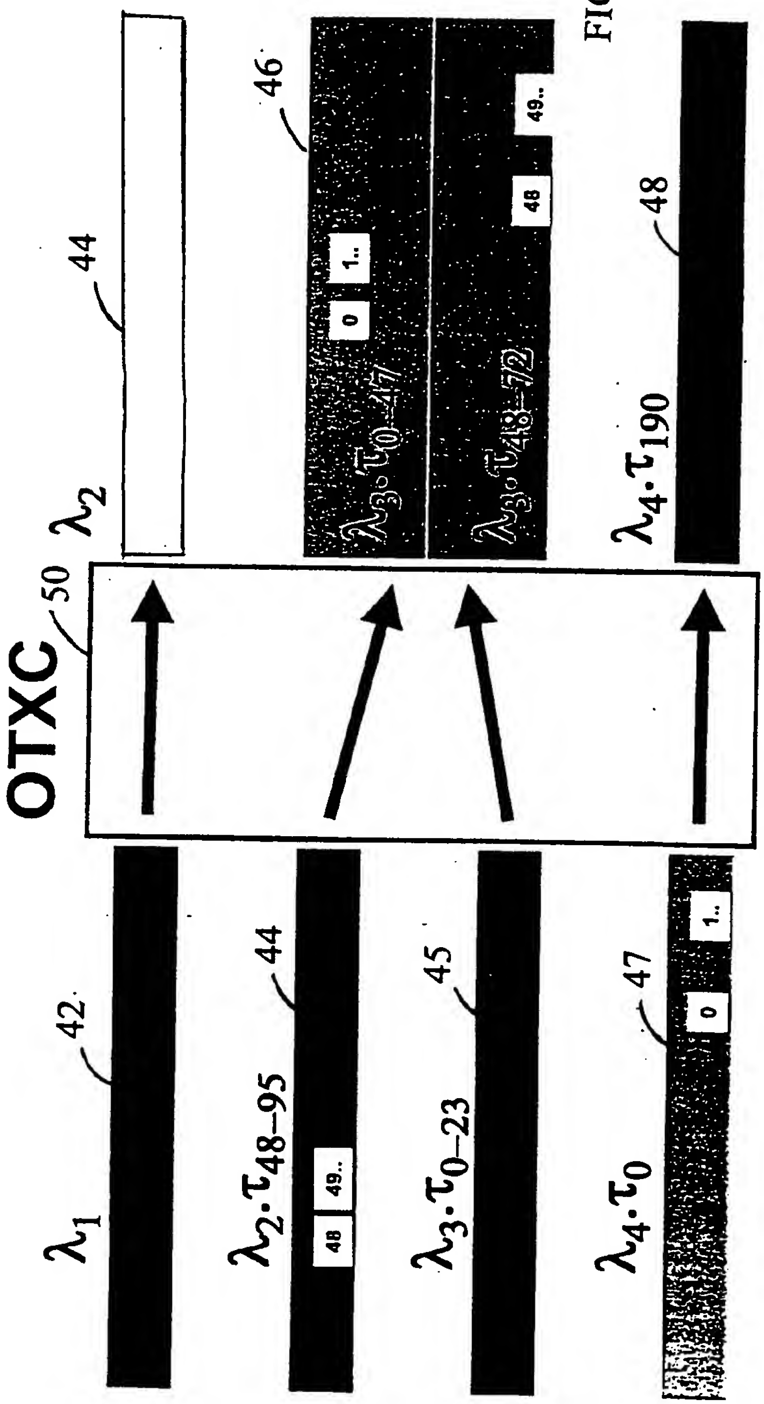

FIG. 5

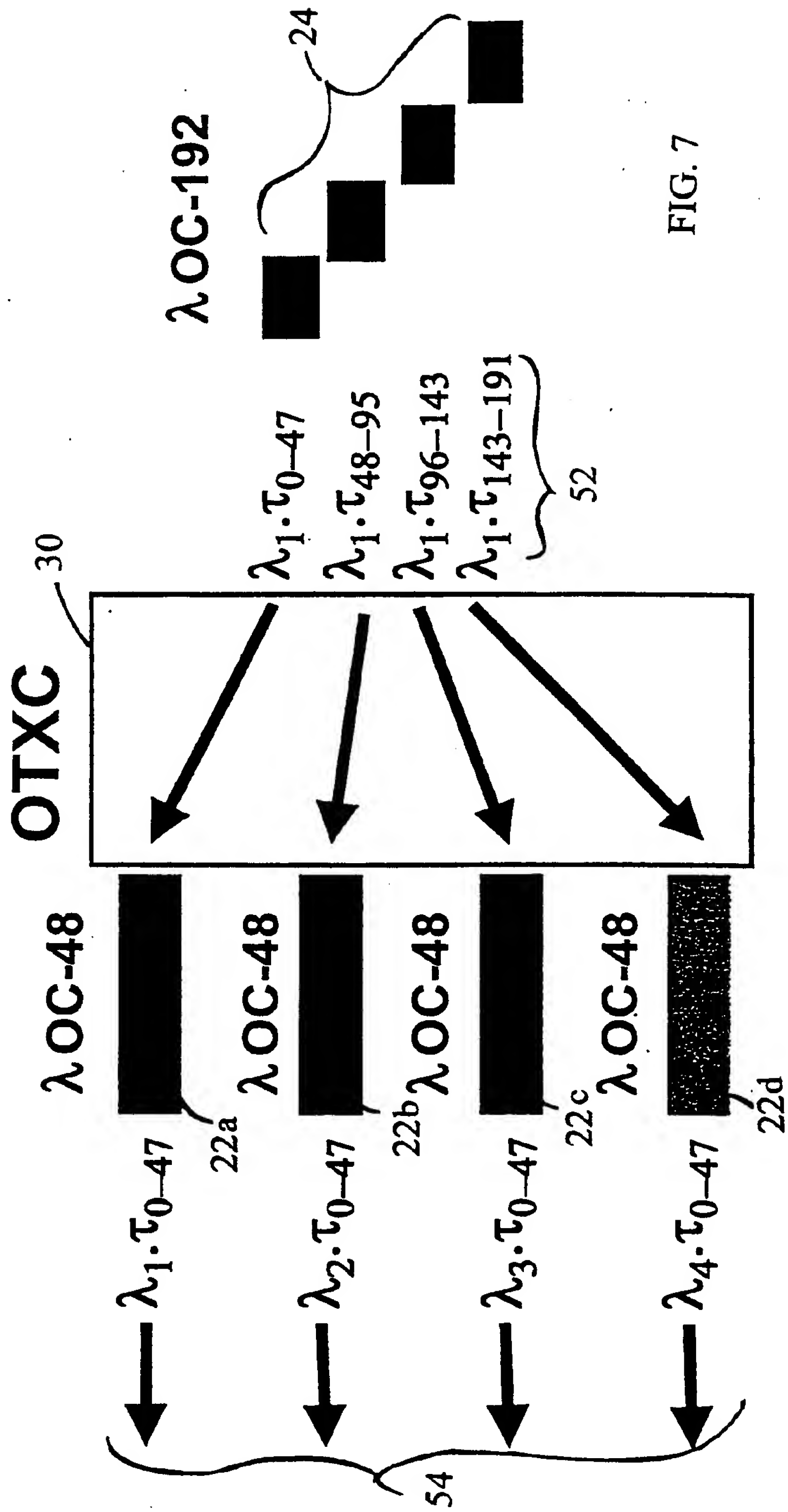
λOC-192
24
30
OTXC
$\lambda_1 \cdot \tau_{0-47}$
$\lambda_1 \cdot \tau_{48-95}$
$\lambda_1 \cdot \tau_{96-143}$
$\lambda_1 \cdot \tau_{143-191}$
52
λOC-48
λOC-48
λOC-48
λOC-48
22a
22b
22c
22d
$\lambda_1 \cdot \tau_{0-47}$
$\lambda_2 \cdot \tau_{0-47}$
$\lambda_3 \cdot \tau_{0-47}$
$\lambda_4 \cdot \tau_{0-47}$
54

FIG. 7

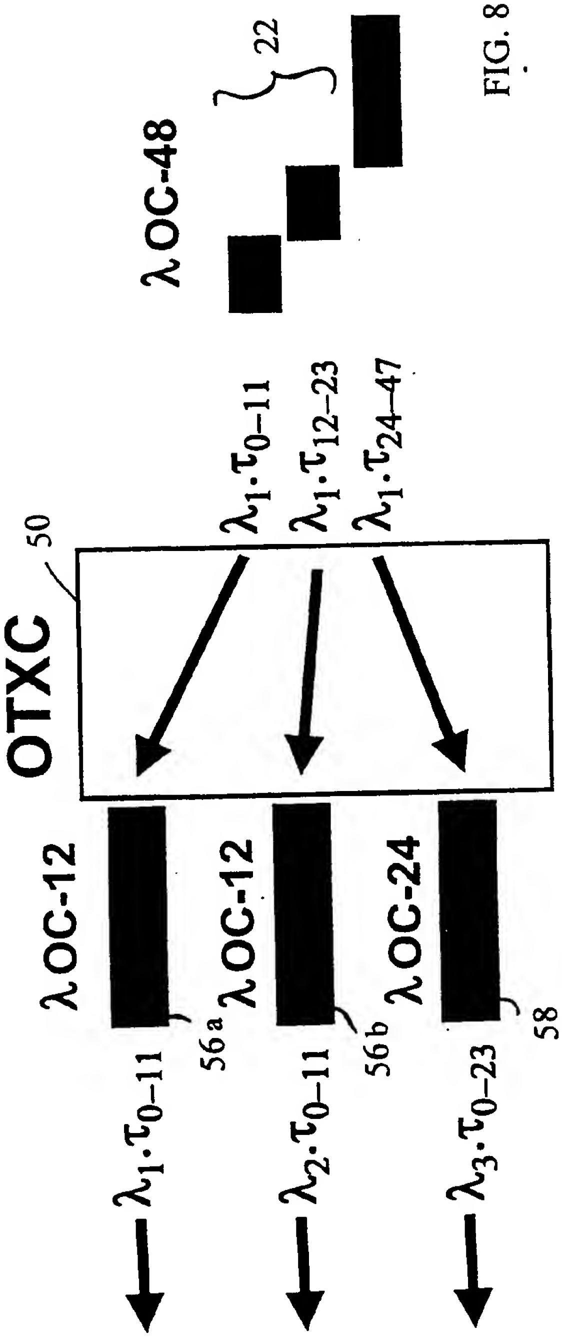
λOC-48
22
OTXC
50
$\lambda_1 \cdot \tau_{0-11}$
$\lambda_1 \cdot \tau_{12-23}$
$\lambda_1 \cdot \tau_{24-47}$
λOC-12
λOC-12
λOC-24
56a
56b
58
$\lambda_1 \cdot \tau_{0-11}$
$\lambda_2 \cdot \tau_{0-11}$
$\lambda_3 \cdot \tau_{0-23}$

FIG. 8

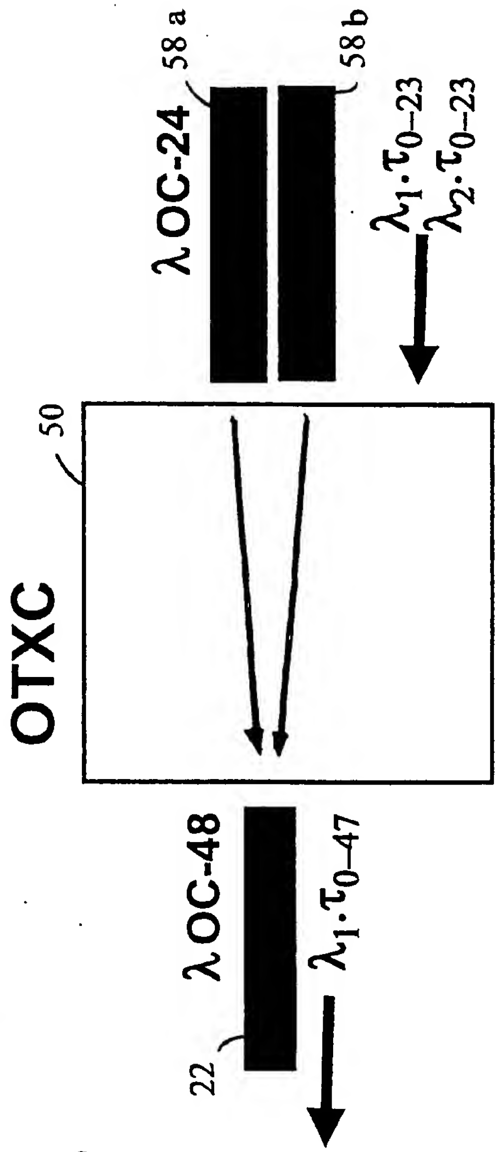
58 a
58 b
λOC-24
$\lambda_1 \cdot \tau_{0-23}$
$\lambda_2 \cdot \tau_{0-23}$
50
OTXC
λOC-48
$\lambda_1 \cdot \tau_{0-47}$
22

FIG. 9